The Effectiveness of Ice Water Immersion in the Treatment of Pain and Reduced Muscle Function Associated with Delayed Onset Muscle Soreness

An Honors Thesis (AT 497)

By

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Abstract

In the field of athletic training, ice water immersion is a commonly used therapeutic intervention when dealing with the signs and symptoms of delayed onset muscle soreness. These signs and symptoms include pain, swelling, stiffness, and reduced force production of the muscle. Ice water immersion involves submerging an athlete in a tub of ice water up to their waist or neck for a prolonged period of time. Ice water immersion is thought to reduce signs and symptoms of delayed onset muscle soreness by limiting the body's acute inflammatory response; however, there is currently no physiological evidence to support these claims. In this critically appraised topic, I will be researching the current literature to find the best evidence on effectiveness of ice water immersion in the treatment of pain and reduced muscle function associated with delayed onset muscle soreness. I will use this evidence to provide a recommendation for current clinical practice and comment on implications for future research.

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CRITICALLY APPRAISED TOPIC (CAT)

The Effectiveness of Ice Water Immersion on the Treatment of Pain and Reduced Muscle Function Associated with Delayed Onset Muscle Soreness

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Clinical Scenario

Ice water immersion is a commonly used recovery intervention for athletes of all calibers despite the lack of conclusive evidence in the literature. Ice water immersion consists of submerging one's body or large body areas in a pool of ice water, and it is thought to counteract the symptoms commonly associated with delayed onset muscle soreness. Delayed onset muscle soreness, also known as DOMS, typically occurs between 24-72 hours after eccentric exercise or the introduction of a new phase or type of exercise training. Symptoms of DOMS include reduction in the force production potential of the muscle, decreased range of motion, and pain that is exacerbated by movement. Many clinicians believe that ice water immersion lessens the acute inflammatory response by causing vasoconstriction which limits tissue permeability and the access of inflammatory mediators to the damaged tissue. The inflammatory response is triggered by exercise-induced muscle damage, and this muscle damage along with the acute inflammatory response is what causes signs and symptoms of DOMS. No clear physiological evidence has yet to confirm the relationship between ice water immersion and decreased delayed-onset muscle soreness.

Focused Clinical Question

Is ice water immersion effective in alleviating the pain and reduced muscle function associated with delayed onset muscle soreness in young adults?

Summary of Search, "Best Evidence" Appraised, and Key Findings

- The literature was searched for studies higher than level 2 evidence that investigated the effects of ice water immersion on the pain and muscle function associated with delayed-onset muscle soreness.
- The literature search returned 8 studies that were related to the clinical question. Of these studies, 4 met the inclusion criteria and were used.
- Three randomized controlled trials and one crossover randomized controlled trial were included.
- Of the included studies, one showed that ice water immersion was effective in reducing muscle function deficits and pain associated with delayed-onset muscle soreness. One other study showed that trends suggest ice water immersion to be effective in reducing pain associated with delayed-onset muscle soreness, and the other two studies showed that ice water immersion was ineffective in improving all outcome measures.

Clinical Bottom Line

There is moderate level 1b evidence to support the use of ice water immersion in the treatment of pain and reduced muscle function associated with delayed onset muscle soreness in young adults. This evidence is based on a protocol with a treatment duration of ten to fifteen minutes.

Strength of Recommendation. Level B evidence exists to support the use of ice water immersion protocols with a treatment duration of ten to fifteen minutes in the treatment of pain and reduced muscle function associated with delayed onset muscle soreness in young adults.

Search Strategy

Terms Used to Guide Search Strategy

- **P**atient Group: collegiate AND athlete AND delayed onset muscle soreness
- **I**ntervention: ice water immersion OR cold water immersion OR cryotherapy
- **C**omparison: control
- **O**utcomes: pain OR reduced muscle function

Sources of Evidence Searched

- PubMed
- Google Scholar
- CINAHL
- SPORTDiscus
- Hand Search of References

Inclusion and Exclusion Criteria

Inclusion

- Limited to humans
- Limited to English language
- Limited to past 10 years (2005-2015)
- Limited to peer reviewed articles
- Studies that used multiple outcome measures, such as serum creatine kinase, visual analog scale, isometric force production, and limb girth

Exclusion

- Studies with no control group
- Articles that were literature reviews and not experimental studies
- Articles that used more than one intervention per experimental group

Results of Search

Four relevant studies1-4 were located and categorized as shown in Table 1 (based on Levels of Evidence, Centre for Evidence Based Medicine, 2009).

Table 1. Summary of Article Designs of Articles Analyzed

Level or Evidence	Study Design / Methodology	Number of Articles	Author (Year)
1b	Randomized Controlled Trial	4	Glasgow et al (2014)[1] Goodall et al (2008)[2] Sellwood et al (2007)[3] Vaile et al (2008)[4]

Best Evidence

The studies in table 2 were labeled best evidence and selected for inclusion in the critically appraised topic (CAT). These studies were included because they are all higher in evidence than a level 2, studied ice water immersion as an intervention in the treatment of delayed-onset

muscle soreness, and described the effect of the intervention on the outcome of interest (pain and muscle function.)

Implications for Practice, Education, and Future Research

Based on this appraisal, only two[1,4] of the four[1-4] studies displayed a positive correlation between the use of ice water immersion protocols with a treatment duration of ten to fifteen minutes and alleviation of pain and reduced muscle function after completing a delayed onset muscle soreness (DOMS)-inducing protocol. These findings[1,4] indicate that ice water immersion protocols with a treatment duration of ten to fifteen minutes are moderately effective in alleviating the pain and reduced muscle function associated with delayed onset muscle soreness. Each study in this appraisal differed in specific points of emphasis such as treatment duration, temperature of treatment water, DOMS-inducing exercise protocol, and the physical activity level of the participants. These differences may have had an impact on the aforementioned findings.

The two studies[1,4] that reported any amount of effectiveness of ice water immersion implemented protocols with a treatment duration of ten to fifteen minutes. The first study[1] implemented multiple different protocols, but found the protocol with a treatment duration of ten minutes at six degrees Celsius to be the only protocol to suggest an effectiveness in alleviating subjective muscle soreness and pain with stretch. The DOMS-inducing exercise protocol used consisted of three sets to fatigue of eccentric lowering using a standing hamstring curl machine. The weight used was calculated based on the subject's concentric one-repetition maximum. The subjects of this study consisted of healthy participants taken from a university student population. The second study[4] to report effectiveness of ice water immersion implemented multiple protocols as well, but found the protocol with a treatment duration of fourteen minutes at fifteen degrees Celsius to be effective in alleviating isometric squat peak force deficits, weighted squat jump peak power deficits, mid-thigh girth deficits, and plasma creatine kinase deficits. The DOMS-inducing exercise protocol used consisted of five sets with ten repetitions of eccentric lowering using a leg press machine. The weight used was 120% of the subject's concentric one-repetition maximum. This was followed by two sets with ten repetitions of eccentric lowering using 100% of the subject's concentric one-repetition maximum. The subjects of this study consisted of strength-trained males.

Of the two studies[2,3] that did not find ice water immersion to be particularly effective in alleviating the pain and reduced muscle function associated with DOMS, only one[2] implemented a protocol with a treatment duration of ten to fifteen minutes. This study implemented a protocol with a treatment duration of twelve minutes at fifteen degrees Celsius. The DOMS-inducing exercise protocol used focused on five sets of twenty drop jumps performed on a concrete-based floor within strict preset time parameters. The subjects of this study consisted of physically active males that were recruited. The other study[3] implemented a protocol with three treatment cycles each a duration of one minute in the water at five degrees Celsius and one minute out of the water. The DOMS-inducing protocol used consisted of five sets of ten repetitions with the

subject eccentrically lowering 120% of their one-repetition maximum on a seated leg extension machine. The subjects for this study consisted of untrained volunteers that responded to poster advertisements.

Clinicians implementing ice water immersion should consider using a protocol with a treatment duration of ten to fifteen minutes to achieve maximal results. They should also stress to their patients the importance of staying immersed in the ice water for the entire duration of the treatment, as it was seen that intermittent ice water immersion was not effective. The clinician should also consider using a protocol that uses a treatment water temperature of five to fifteen degrees Celsius as this allows for optimum cooling of the targeted tissues. Clinicians should also take into account that DOMS was induced in a controlled, experimental environment in each of these studies. DOMS was not induced in a functional manner as it will be with athletes. This might have an effect on the way DOMS responds to ice water immersion as the type of muscle damage may be slightly different. However, there is no physiological or experimental evidence to support this claim. This is simply something that clinicians should be aware of when implementing ice water immersion in the treatment of DOMS. They should also be aware that psychological factors may play a large role in the effectiveness of the treatment. Since this intervention is so widely used, many athletes are already convinced of its effectiveness without conclusive evidence in the literature. The placebo effect may contribute greatly to the effectiveness of the treatment with individuals such as this and produce better results than are seen in this critically appraised topic.

Future research regarding ice water immersion protocols that are effective in alleviating pain and reduced muscle function associated with DOMS should include prospective randomized controlled trials that allow for blinding of the assessors to strengthen study quality. Although a DOMS-inducing exercise protocol was implemented in each study, these protocols did not incorporate functional exercise. Future research might look at the use of ice water immersion in the treatment of pain and reduced muscle function associated with DOMS when the DOMS is induced by functional movement as it would most often be in an athletic population. The optimal treatment duration and treatment temperature are also important factors to be looked at by future research. Many of the studies in this critically appraised topic used different treatment durations and treatment water temperatures. It is plausible that the treatment duration and water temperature play a large part in the treatment's effectiveness. With this in mind, future research could reasonably study these two factors in prospective randomized controlled. In clinical practice today, approximate values based on other cryotherapy techniques are used to determine treatment duration and temperature. To really examine the effectiveness of a treatment protocol, these two factors must be studied. Future research should also try to include larger populations and populations more equal in gender to strengthen the study quality. In addition, future studies should utilize athletic participants so the results may be more directly applied to athletic training and athletes. This CAT should be reviewed in two years to determine whether additional best evidence has been published that may change the clinical bottom line for this specific clinical question.

Table 2. Characteristics of Included Studies

	GLASGOW ET AL (2014)[1]	GOODALL ET AL (2008)[2]	SELLWOOD ET AL (2007)[3]	VAILE ET AL (2008)[4]
STUDY DESIGN	Randomized Controlled Trial	Randomized Controlled Trial	Randomized Controlled Trial	Randomized Controlled Trial
PARTICIPANTS	50 healthy participants from student population at University of Ulster (32 male, 18 female; 18-35 years; height 1.79 ± 0.06m; body mass 81.9 ± 17kg) Advised to refrain from any unaccustomed physical activity during study, but advised to continue normal physical activity Excluded from study for following contraindications: skin allergy, broken skin, open wounds, abnormal or altered skin sensation, epilepsy, asthma, chlorine allergy, Raynaud's disease, peripheral vascular disease, cryogobinaemia or under the influence of alcohol Assigned to groups using a computer generated	18 physically active male subjects were recruited for this study (age 24 ± 5 years; height 1.82 ± 0.06m; body mass 85.7 ± 16.6kg) Not familiar with eccentric based training and were asked to refrain from any form of resistance training or exercise that may potentially cause muscle damage and soreness for 3 weeks prior to and for the duration of testing Asked to refrain from NSAIDs and nutritional supplements during testing Equally but randomly allocated to either the treatment or control group The dropout rate was not discussed	40 volunteers that responded to poster advertisements throughout the Schools of Physiotherapy and Medicine, University of Melbourne, Melbourne, Victoria, Australia (11 male, 29 female; age 21.4 ± 4.3 years; height 1.67 ± 0.09m; body mass 63 ± 11kg; body mass index 22 ± 3kg/m^2) Excluded from the study for the following history of eccentric quadriceps exercise in the past 3 months, history of quadriceps muscle tear, neurological disease involving lower limbs, current lower limb musculoskeletal injury, inability to understand English, and potential vascular problems in which ice water immersion is contraindicated	38 strength trained males completed two experimental trials separated by 8 months; passive recovery trial and specific hydrotherapy protocol trial Completed a comprehensive familiarization session on the leg press machine, squat, squat jump, and isometric squat protocols until no further learning or improvement were apparent Randomly assigned to one of four groups: control, cold water immersion, hot water immersion, or contrast water

	GLASGOW ET AL (2014)[1]	GOODALL ET AL (2008)[2]	SELLWOOD ET AL (2007)[3]	VAILE ET AL (2008)[4]
	randomization sequence There were no dropouts in this study There were no significant differences between groups at baseline	There were no significant differences between groups at baseline	Group randomization was generated using a random numbers table and allocation was concealed using sequentially numbered opaque envelopes held at a central location There were no dropouts in this study There were no significant differences between groups at baseline	therapy The dropout rate was not discussed There were no significant differences between groups at baseline
INTERVENTION INVESTIGATED	DOMS was induced to the non-dominant knee flexors using a standing hamstring curl machine. The concentric one-repetition maximum was established, and this weight was used during the induction protocol During testing, weight was raised by an experimenter to the start position. The subjects then lowered the weight eccentrically over	DOMS was induced by participants dropping from a 0.6m box, and upon landing jumped up maximally, landing on the same surface Five sets of twenty drop jumps were performed on a concrete based flood, in time with a set of recorded beeps allowing 10 seconds rest between each jump and 2 minutes rest between sets	DOMS-inducing exercise protocol was carried out on a seated leg extension machine using the non-dominant leg only. The concentric one-repetition maximum was established for each participant. 120% of the one-repetition maximum was used as the weight to be lowered eccentrically by the non-dominant leg during testing	DOMS-inducing exercise protocol consisted of 5 sets of 10 repetitions bilateral leg press contractions with load of 120% of one-repetition maximum followed by 2 sets of 10 repetitions at load of 100% one-repetition maximum Eccentric contractions lasted 3-

	GLASGOW ET AL (2014)[1]	GOODALL ET AL (2008)[2]	SELLWOOD ET AL (2007)[3]	VAILE ET AL (2008)[4]
	three seconds by following researcher instructions. Participants undertook three sets of eccentric hamstring contractions to fatigue with one minute rest between sets Participants attended five consecutive days, intervention was applied on the first three days Short contrast immersion participants were immersed for 1 minute in 38 degrees Celsius water followed by 1 minute in 10 degrees Celsius water repeated for 3 rounds Short intermittent cold water immersion participants were immersed in 10 degrees Celsius water for 1 minute followed by no immersion for 1 minutes repeated for 3 rounds	Cryotherapy group obtained seated immersion in a 15 degree Celsius ice bath for 12 minutes with legs kept apart to ensure maximum surface area exposure The control group remained seated for the same amount of time as the immersion was administered for but received no treatment Interventions were applied immediately post exercise and every 24 hours thereafter for the following three days Outcome measures were taken at baseline, 24 hours, 48 hours, 72 hours, and 96 hours	Each participant completed 5 sets of 10 repetitions total with 1 minute rest between each set Water immersion was carried out immediately after eccentric exercise protocol Participants were submerged to the anterior superior iliac spines Participants in the treatment groups were immersed in melting ice water at 5 degrees Celsius Participants in the control group were immersed in tepid water at 24 degrees Celsius Participants remained in the water for 1 minute, followed by 1 minute out of the water. This cycle repeated 3 times. Outcome measures were taken at baseline, 24 hours,	5 seconds with the load being raised by an electrical winch after each contraction. One contraction was completed every 15 seconds with a 3 minute rest between sets Following the testing session, then once a day for 72 hours post exercise, subjects performed either passive or hydrotherapy recovery interventions Passive recovery/control participants were seated with minimal to no movement for 14 minutes Cold water immersion participants immersed

	GLASGOW ET AL (2014)[1]	GOODALL ET AL (2008)[2]	SELLWOOD ET AL (2007)[3]	VAILE ET AL (2008)[4]
	Cold water immersion participants were immersed in 10 degrees Celsius water for 10 minutes A different group of cold water immersion participants were immersed in 6 degrees Celsius water for 10 minutes Control group participants had a seated rest with no immersion for 10 minutes Participants were immersed up to waist level in a standing position Water temperature was thermostatically controlled, and water jets were active for the entire intervention period Outcome measures were taken at 0 hours (baseline), 24 hours, 48 hours, 72, hours, and 96 hours		48 hours, and 72 hours Investigator responsible for outcome assessments was blinded to group allocation. Participants were blinded to which intervention was considered therapeutic.	body up to neck in 15 degree Celsius water for 14 minutes Hot water immersion participants immersed body up to neck in 38 degree Celsius water for 14 minutes Contrast water therapy participants immersed body up to neck in 15 degree Celsius water for 1 minute and 38 degree Celsius water for 1 minute alternating for a total of 14 minutes Primary outcome measures were taken at baseline, 24 hours, 48 hours, and 72 hours

	GLASGOW ET AL (2014)[1]	GOODALL ET AL (2008)[2]	SELLWOOD ET AL (2007)[3]	VAILE ET AL (2008)[4]
OUTCOME MEASURE(S)	Primary Outcome Measures: subjective muscle soreness Secondary Outcome Measures: active range of motion (AROM), pain on stretch (POS), concentric peak torque (CPT), and creatine kinase (CK) levels	Primary Outcome Measures: maximal voluntary contraction (MVC) of knee extensors, plasma creatine kinase (CK) activity, delayed onset muscle soreness (DOMS), knee flexion range of motion (ROM),swelling	Primary Outcome Measures: pain and tenderness using the visual analog scale (VAS), swelling, one-legged hop-for-distance test, maximal isometric quadriceps strength, serum creatine kinase (CK)	Primary Outcome Measures: isometric squat force, squat jump performance, creatine kinase (CK), myoglobin (Mb), interleukin-6 (IL-6), lactate dehydrogenase (LDH), thigh circumference, and perceived muscle soreness
MAIN FINDINGS	Muscle soreness peaked at day 2 post exercise Muscle strength was lowest between day 1 and day 2 post exercise CK activity peaked between day 3 and day 4 post exercise No significant interaction effects for AROM (P=0.890), POS (P=0.444), muscle strength (P=0.499) Largest effect sizes for	In both groups, CK activity peaked 24 hours post exercise and returned to baseline values by 96 hours post exercise Difference between groups were approaching significance (P=0.058) No difference were found between conditions in MVC (P=0.783) Muscle soreness peaked 48 hours post exercise and returned to baseline levels	In both groups, serum CK increased significantly and maximum isometric strength decreased significantly at 24 hours (P<0.001, P=0.001, P=0.002, and P=0.025, respectively) Intervention group showed a greater increase at 24 hours in pain on sit-to-stand (P=0.009) No significant differences were noticed between groups in regard to any other outcome measure	Change in isometric squat performance was significantly less at 24, 48, and 72 hours post exercise following hot water immersion (P<0.05) compared to passive recovery and contrast water therapy (P<0.01) compared to passive recovery Change in isometric squat performance was significantly less at 48 and 72 hours

	GLASGOW ET AL (2014)[1]	GOODALL ET AL (2008)[2]	SELLWOOD ET AL (2007)[3]	VAILE ET AL (2008)[4]
	muscle soreness at 48 hours [MD of 2.05cm (95% CI – 0.4 to 4.5) based on 10cm VAS) and 72 hours [MD of 1.06 (95% CI – 0.2 to 2.32) based on 10cm VAS] were in favor of 10 minute cold water immersion at 6 degrees Celsius group Trends in favor of 10 minute cold water immersion at 6 degrees Celsius over the control group for POS at 48 hours [MD of 1.7cm (95% CI – 0.69 to 4.09) based on a 10cm VAS] and 72 hours [MD of 0.58cm (95% CI – 1.68 to 2.84) based on a 10cm VAS] post exercise	by 96 hours post exercise ROM did not significantly change over time and was not significantly different between the groups An increase was shown in thigh circumference, but differences were not significant (P≥0.05)		following cold water immersion (P<0.05) compared to passive recovery Change in peak power performance was significantly less at 48 hours (P=0.01) after cold water immersion and at 24, 48, and 72 hours after contrast water therapy (P<0.01) Production of peak power was significantly reduced below baseline 72 hours post exercise after hot water immersion and passive recovery (P>0.05) Mid-thigh girth was significantly reduced at 24, 48, and 72 hours after cold water immersion (P<0.03) and contrast water

	GLASGOW ET AL (2014)[1]	GOODALL ET AL (2008)[2]	SELLWOOD ET AL (2007)[3]	VAILE ET AL (2008)[4]
				therapy (P<0.01) compared to passive recovery Serum CK was significantly reduced at 24 (P=0.03) and 72 hours (P=0.04) post exercise after cold water immersion, and 48 hours after hot water immersion compared to passive recovery Perception of pain reduced at 24, 48, and 72 hours post exercise after contrast water therapy (P<0.01) compared to passive recovery
LEVEL OF EVIDENCE	1b	1b	1b	1b
VALIDITY SCORE	PEDro 9/10	PEDro 5/10	PEDro 9/10	PEDro 5/10
CONCLUSION	Cold water immersion has greatest effect on subjective muscle soreness and POS rather than the	Cold water immersion did not enhance recovery from exercise-induced muscle damage	Ice water immersion was ineffective in minimizing or preventing symptoms of muscle damage after	Cold water immersion and contrast water therapy are effective

	GLASGOW ET AL (2014)[1]	GOODALL ET AL (2008)[2]	SELLWOOD ET AL (2007)[3]	VAILE ET AL (2008)[4]
	other objective outcome measures Longer immersions in colder water are associated with less muscle soreness, but no strong evidence to suggest an optimal treatment dosage was found		eccentric exercise	in minimizing the physiological and functional deficits associated with DOMS Hot water immersion was effective in the recovery of isometric force, but ineffective for recovery of all other markers

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